A Regime-Based Evaluation of TRMM Oceanic Precipitation Biases

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Background/Motivation

The 17+ year TRMM rain rate record contains significant spatial and temporal differences between the TRMM TMI and TRMM PR oceanic rainfall estimates. While Figure 1 shows the mean spatial pattern of these differences, these patterns are highly correlated with interannual variability associated with El Niño as shown in Figure 2. To understand and to attempt to reconcile these differences the following analysis was performed.

- Use TRMM-derived precipitation regimes to compare TRMM TMI and PR rain rates to polarimetrically-tuned rain rates from the Kwajalein Atoll.
- Assess the degree to which bias estimates based on the Kwajalein radar comparison can explain PR-TMI rainfall differences in interannual variability associated with ENSO.
- Apply these results to understand associated errors in the GPROF (i.e. TMI) retrieval algorithm and develop potential methods to reduce these errors.

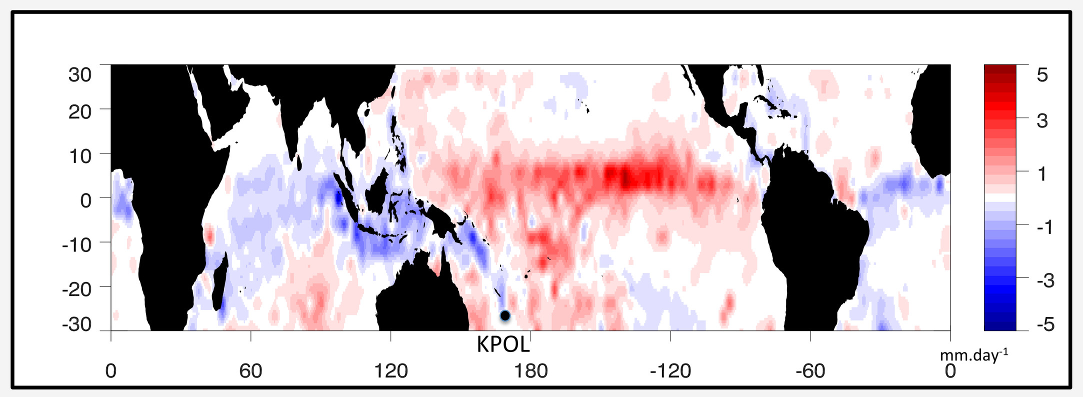

Figure 1: TMI-PR differences DJF 2009-2010

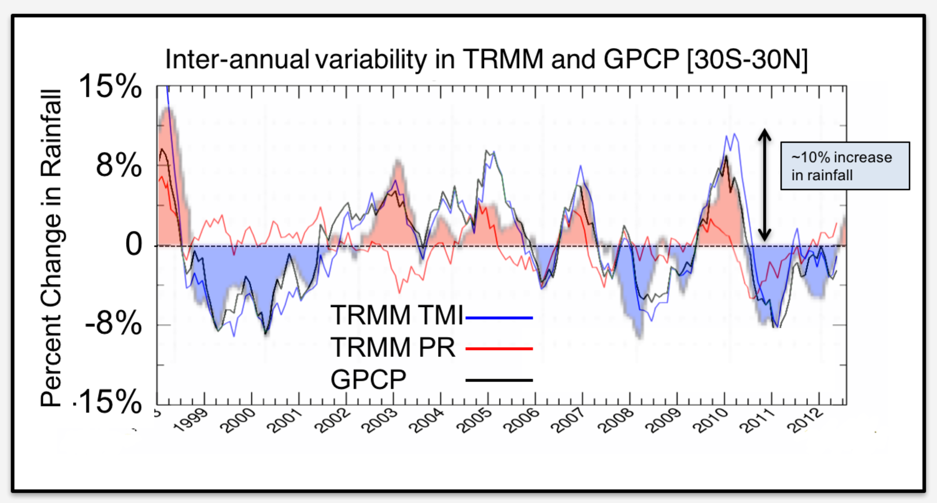

Figure 2: TMI and PR oceanic rain rate anomalies 25S-25N

Comparisons with Kwajalein KPOL Radar

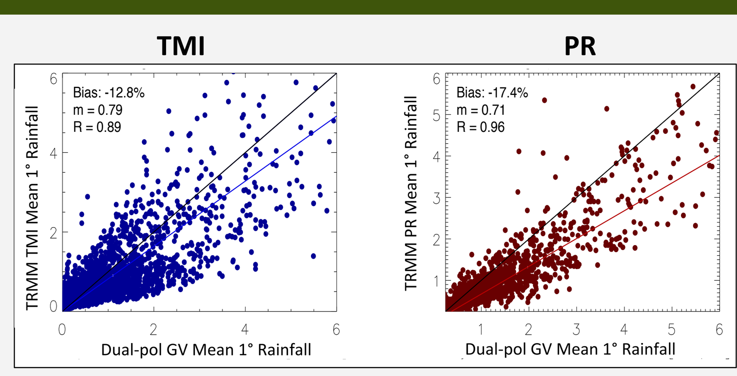

Figure 3: Scatterplots of TMI (left) and PR (right) rain rates vs Kwaj GV averaged over 1° × 1° boxes

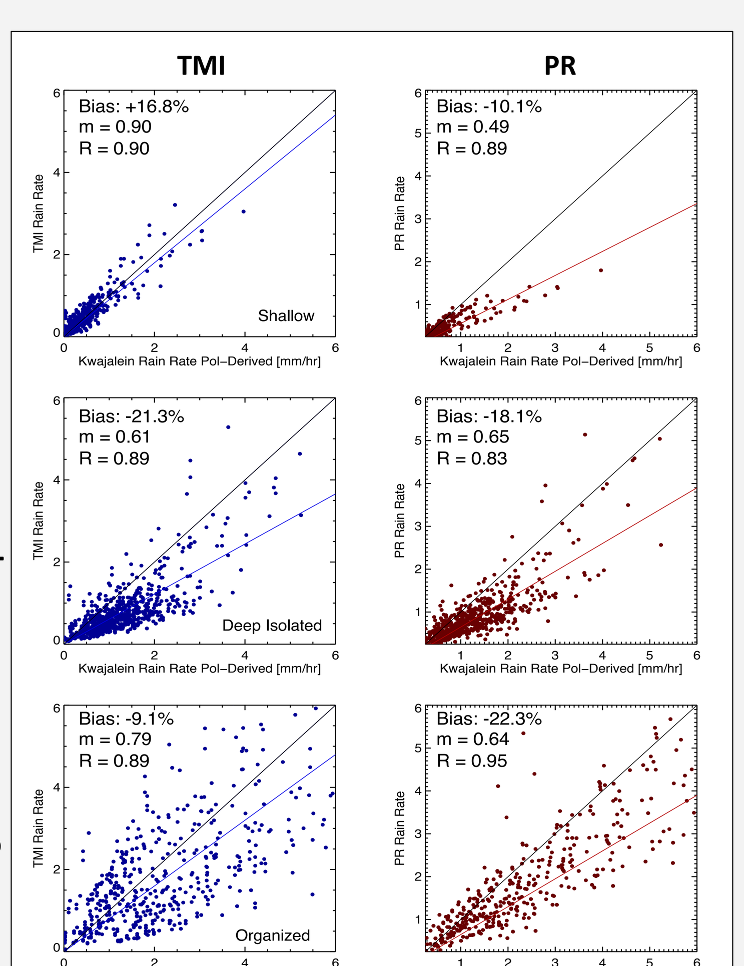

Figure 4: TMI and PR rain rates vs Kwaj GV for shallow (top), deep isolated (middle) and organized (bottom) regimes.

1) Collocate TRMM and Kwajalein KPOL Rainfall Data

- KPOL Polarimetrically-tuned based on Bringi et al (2004)
- TRMM 2A12 and TRMM 2A25

2) Classify by Regime

(Elsaesser et al. (2010), Elsaesser and Kummerow (2013))

Classifies rainfall in 1° × 1° boxes using clustering technique as one of 3 types.

- Shallow
- Deep Isolated
- Organized

3) Compare TMI, PR, and Kwajalein rain rates (2008-2014)

➢ The PR rain rate biases are somewhat distinct for each precipitation regime; however, TMI exhibits positive and negative bias associated with the organized precipitation regimes.

Rain Rate Biases by Regime and Convective/Stratiform

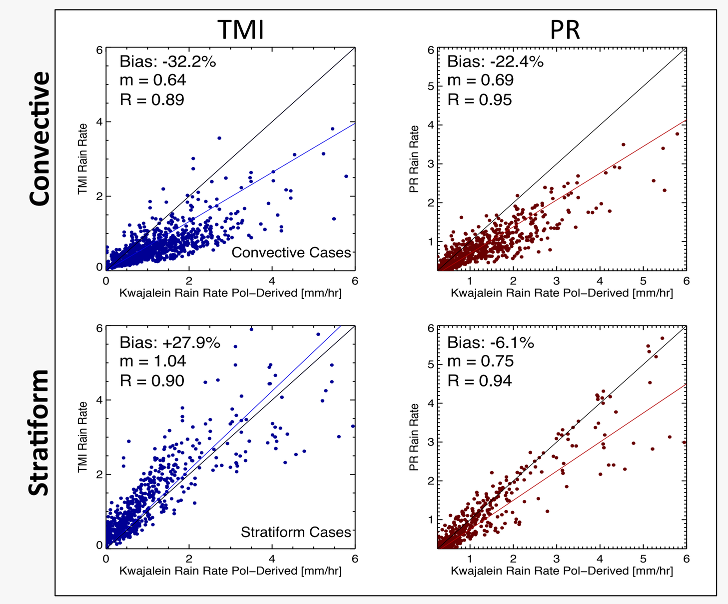

Figure 5: Mean TMI (left) and PR (right) rain rates vs Kwaj GV as a function of convective fraction over 1°× 1° boxes

➢ The convective and stratiform cases reveal clear bias separation.
➢ Regime-based validation pinpoints bias sources (below left)

PR-TMI Biases at 1°x1° scale

Convective	All	Shallow	Deep Iso.	Organized
PR Bias [%]	-22.4	-12.8	**-23.4**	-26.1
TMI Bias [%]	-32.2	+5.5	**-37.8**	-30.3
Stratiform				
PR Bias [%]	-6.1	-11.4	-8.4	-2.6
TMI Bias [%]	+27.9	+25.5	+8.1	**+33.4**

PR-TMI Biases at TMI FOV scale

Convective	All	Shallow	Deep Iso.	Organized
PR Bias [%]	-34.8	-15.9	**-52.2**	-28.6
TMI Bias [%]	-50.9	-30.9	**-66.8**	-47.9
Stratiform				
PR Bias [%]	+17.2	-22.4	+24.0	+7.4
TMI Bias [%]	+77.8	+13.2	**+49.4**	**+92.3**

El Niño and La Niña Time Periods near Kwajalein

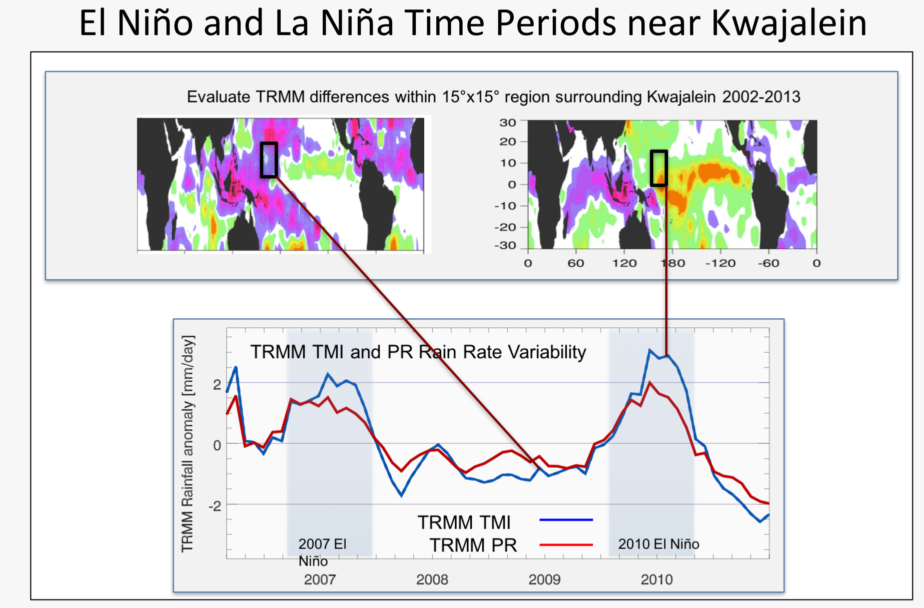

Figure 6: Differences in TMI and PR rainfall variability associated with ENSO for the region around Kwajalein

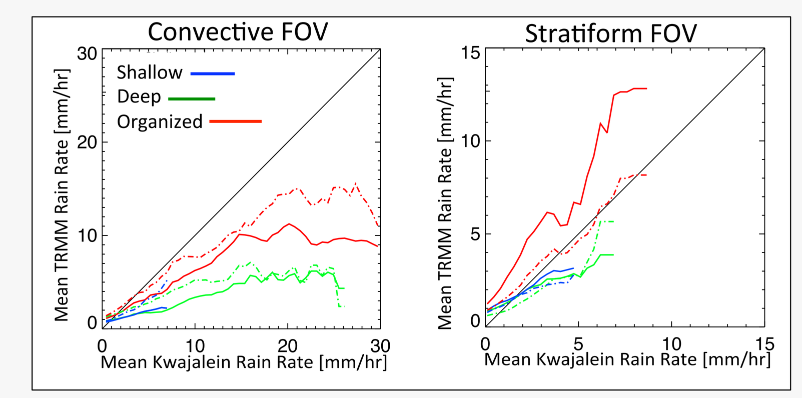

Figure 7: Comparison of PR (dashed) and TMI (solid) mean rain rates with GV at the TMI FOV scale. (defined as convective or stratiform RR fraction > 90% in TMI FOV) .

➢ TMI and PR underestimate GV rain rates in convective rainfall in nearly all precipitation regimes (TMI underestimates GV and PR).
➢ Large positive biases are observed in TMI stratiform rainfall for organized precipitation regimes.

Relating TRMM Biases to Regimes during ENSO

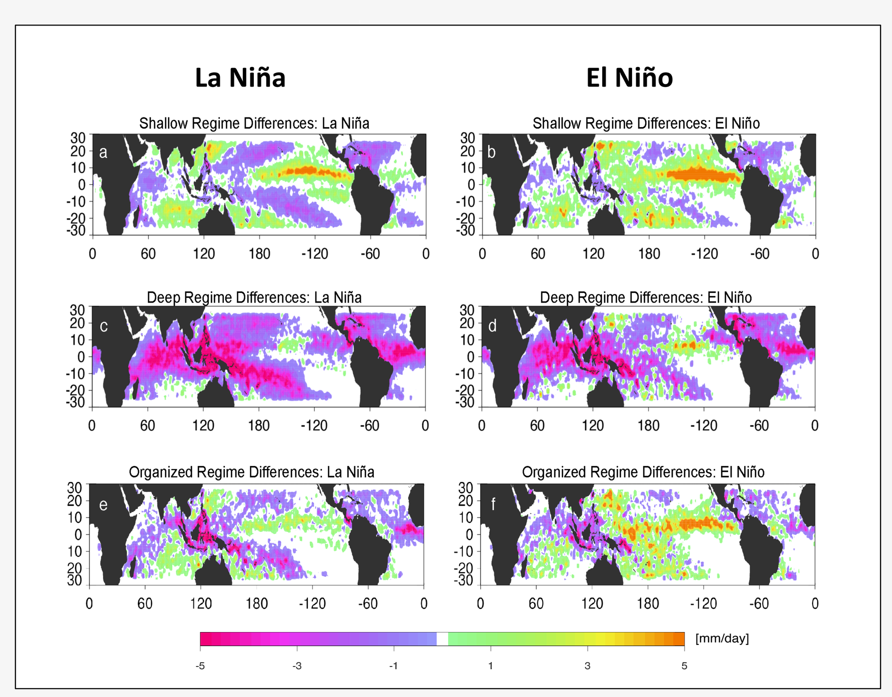

Figure 8: PR-TMI differences due to biases associated with regimes based on the comparison with Kwaj GV radar data.

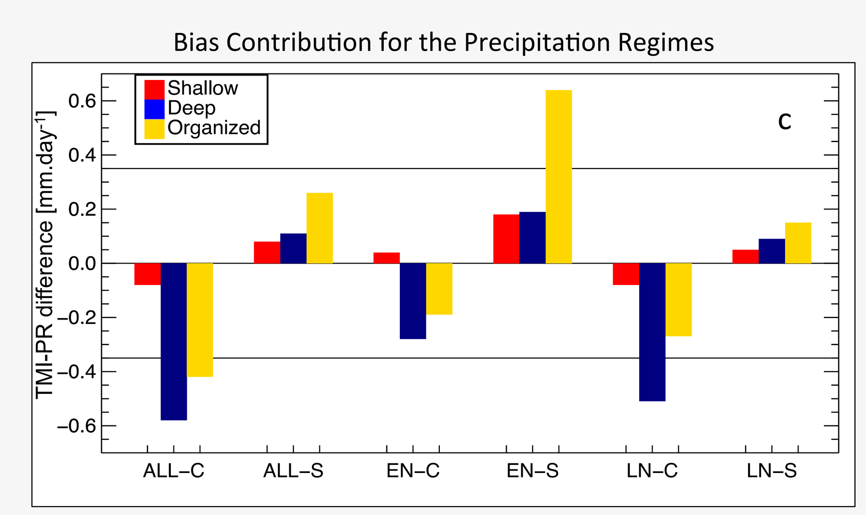

Figure 9: Contributions to TMI-PR rain rate differences for El Niño (EN), La Niña (LN) and all cases (ALL) as a function of precipitation split by convective fraction into (C) convective cases and (S) stratiform cases.

➢ El Niño: Increase occurrence in organized precipitation regimes are associated with more stratiform rainfall, which drives the large positive difference observed between TMI and PR rain rates.

➢ La Niña: Rain rates are driven by deep isolated precipitation regimes leading to a negative difference observed between TMI and PR rain rates.

Regime-based Bias Correction

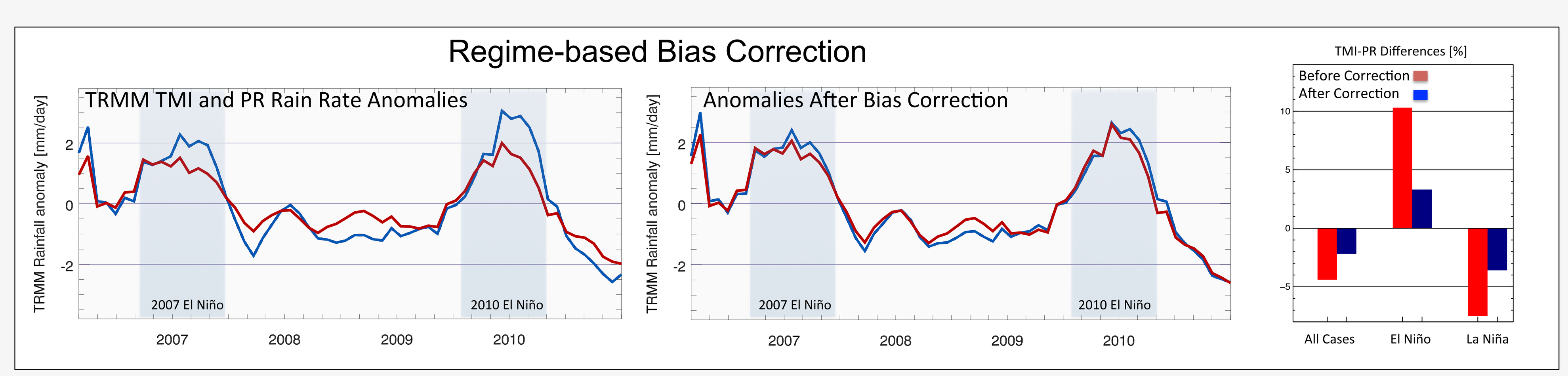

Figure 10: (left) TMI and PR rain rate anomalies in 15° region surrounding the Kwajalein Atoll. Using values from the above tables, (middle) we apply a bias correction to test the regimes representation of interannual variability. (right) TMI-PR differences (red) before and (blue) after correction.

➢ Application of bias correction reduces TMI-PR differences associated with El Nino by 70%.

Convective-Stratiform Partitioning in GPROF

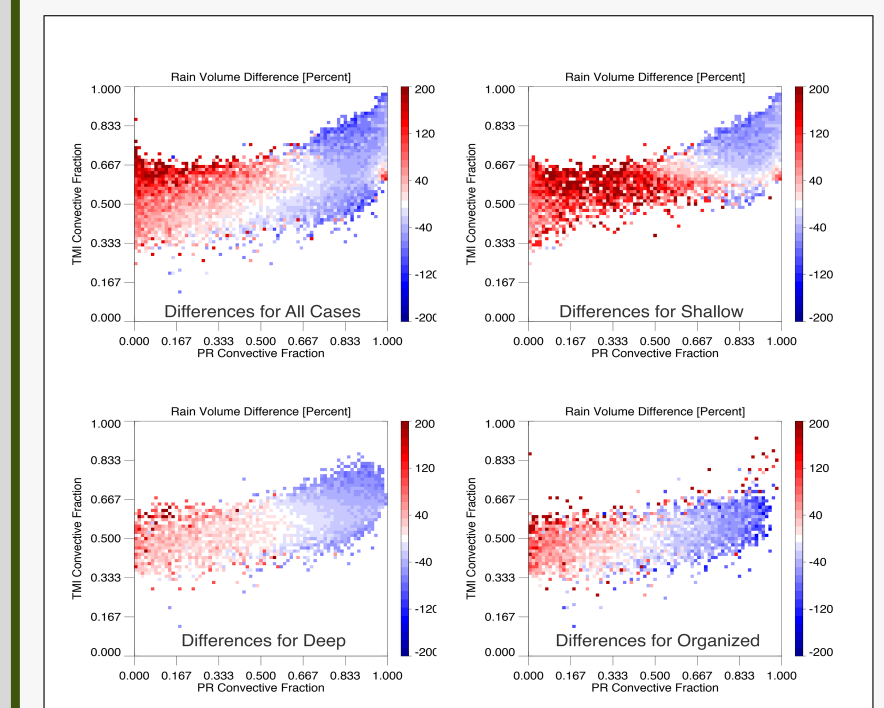

Figure 11: TMI-PR differences [%] within a 15° region surrounding the Kwajalein Atoll as a function of convective fraction and precipitation regime (2008-2010).

➢ The GPROF retrieval struggles to accurately differentiate convective and stratiform rainfall.

➢ Differences between the TMI and PR retrievals are not uniform, but in fact vary uniquely for each precipitation regime.

➢ Rain rate biases over the ocean in GPROF 2014 are positive for stratiform rain rates and largely negative for convective rain rates.

➢ Constraining the convective fraction to ±15% reduces biases up to 80% in higher convective fractions and 70-80% in predominantly stratiform rain rates.

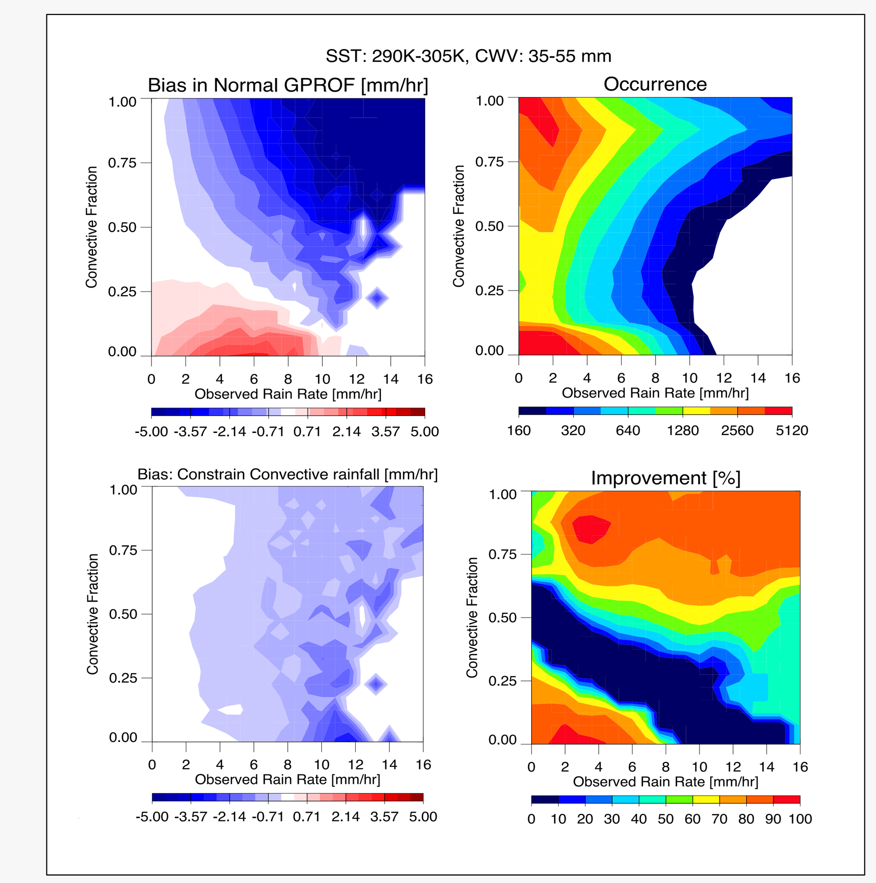

Figure 12: Differences between (top) GPROF-retrieved rain rates and a priori database entries (used as "observational" input) and (bottom) the improvement when constraining the convective fraction in the Bayesian procedures by ±15%.

Summary and Conclusions

Biases in TRMM PR and TMI rain rate estimates are determined as a function of precipitation regime using collocated Kwajalein GV data from 2008-2014. Bias corrections from the Kwajalein GV comparisons based on the defined precipitation regimes are then applied globally to reconcile PR and TMI oceanic rain rate discrepancies associated with ENSO.

- Radar data (e.g. TRMM PR, DPR, GV) is used to determine the characteristics of precipitating systems upon which the regime-based bias analysis is performed.
- Based on the comparison with Kwajalein radar data, both PR and TMI have large negative (low) biases associated with deep isolated convection whereas positive (high) biases are associated with stratiform rainfall (as much as 92% for TMI rain rates in organized regimes).
- Convective and stratiform partitioning helps to separate biases, however, including the precipitation regime classification pinpoints the bias sources.
- Increased occurrence in organized precipitating systems directly relates to the large discrepancies found during El Niño time periods (explains 81% of TMI-PR difference).
- A clear relationship exists in precipitation regime frequency and rain rate differences.
- GPROF struggles to correctly differentiate convective and stratiform precipitation, but efforts are under way to improve the convective partitioning, which could help to significantly reduce biases in the GPROF precipitation estimates.

Publications:

Henderson, D. S., C. D. Kummerow and W. Berg, 2017: ENSO Influences on TRMM Tropical Oceanic Precipitation Characteristics and Rain Rates, J. Climate, *accepted pending revisions.*

Henderson, D. S. and C. D. Kummerow, 2017: Sensitivity of Rain-Rate Estimates Related to Convective Organization: Observations from the Kwajalein, RMI, Radar, *J. Appl. Meteor. Climatol.,* **56**, 1099-1119.

Acknowledgements

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